Section 9

Spacecraft Technologies

- *Wideband Advanced Recorder / Processor (WARP)*
- *X-Band Phased Array Antenna*
- *Enhanced Formation Flying*
- *Carbon-Carbon Radiator*
- *Pulse Plasma Thruster*
- *Lightweight Flexible Solar Array*

Wideband Advanced Recorder Processor (WARP)

Technology Enabler

Description:

High Rate (up to 840Mbps capability), high density (48Gbit storage), low weight (less than 25.0 Kg) Solid State Recorder/Processor with X-band modulation capability.

Utilizes advanced integrated integrated circuit packaging (3D stacked memory devices) and “chip on board” bonding techniques to obtain extremely high density memory storage per board (24Gbits/memory card)

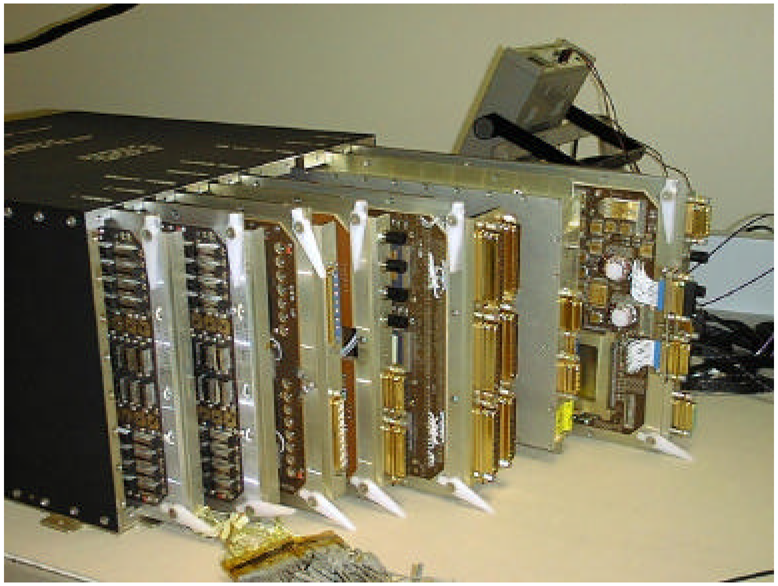
Includes high capacity Mongoose 5 processor which can perform on-orbit data collection, compression and processing of land image scenes.

Validation:

The WARP is required to store and transmit back science image files for the AC, ALI and Hyperion.

Partners:

Litton Amecom



Benefits to Future Missions:

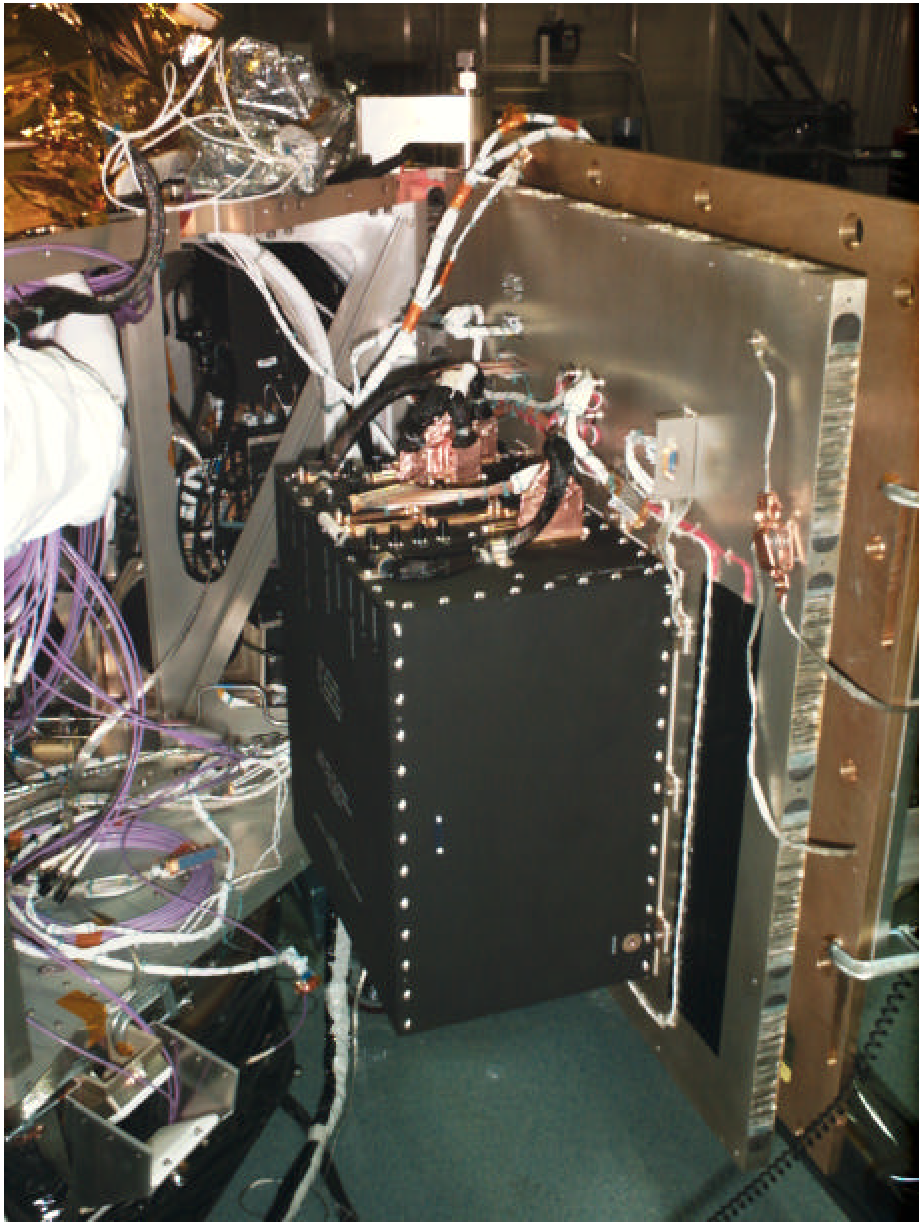
The WARP will validate a number of high density electronic board advanced packaging techniques and will provide the highest rate solid state recorder NASA has ever flown.

Its basic architecture and underlying technologies will be required for future earth imaging missions which need to collect, store and process high rate land imaging data.

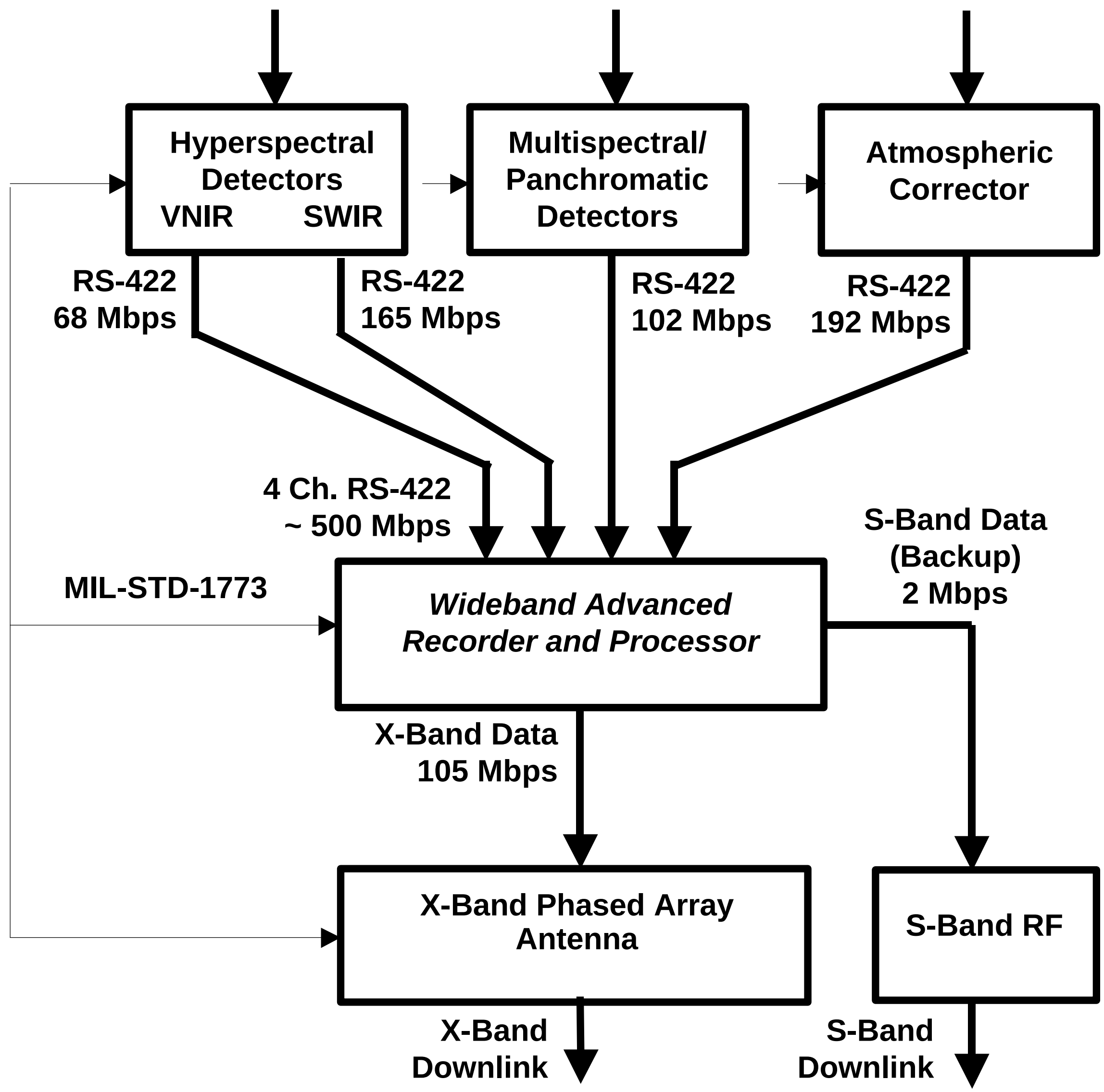
Top-Level Specifications

Data Storage:	48 Gbits
Data Record Rate:	> 1 Gbps Burst
	900 Mbps Continuous (6 times faster than L7 SSR)
Data Playback Rate:	105 Mbps X-Band (with built-in RF modulator)
	2 Mbps S-Band
Data Processing:	Post-Record Data Processing Capability
Size:	25 x 39 x 37 cm
Mass:	22 kg
Power:	38 W Orbital Average., 87 W Peak
Thermal:	15 - 40 °C Minimum Operating Range
Mission Life:	1 Year Minimum, 1999 Launch
Radiation:	15 krad Minimum Total Dose, LET 35 MeV

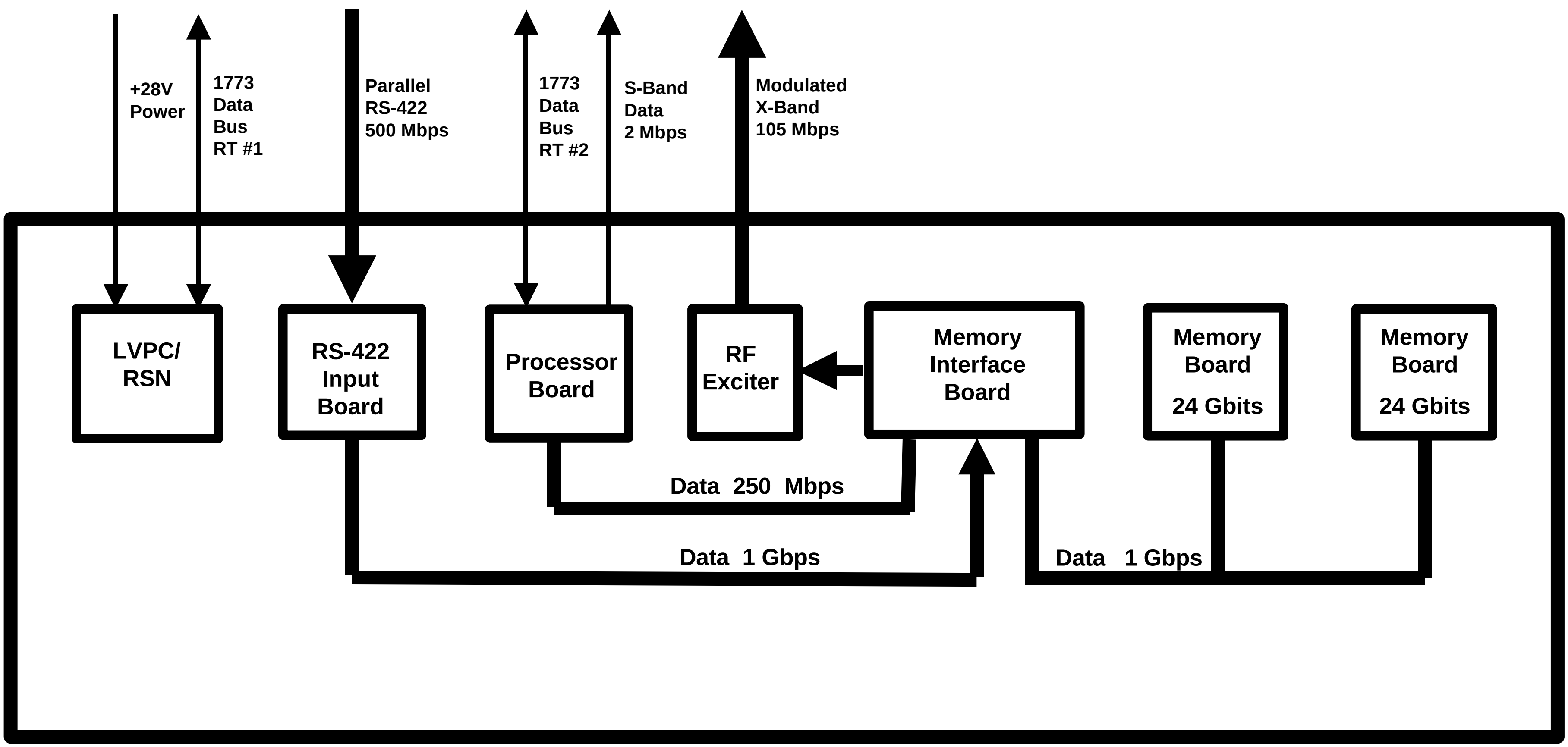
WARP on Spacecraft, Bay 1



EO-1 Flight Data System Architecture



WARP Flight Hardware Architecture



WARP Infusion Opportunities

- ***NASA owns the WARP design***
- ***WARP was built in association with Litton Amecom***
- ***WARP is particularly applicable to missions with the following:***
  - *High ingest data rates £ 1.0 Gigabit / second*
  - *Need for processing capability on board*
  - *Use of phased array antenna as primary downlink*
- ***WARP was single-string for EO-1 but reliability enhancements have already been designed***
- ***Technical support to facilitate infusion is negotiable***
- ***For further information, contact:***

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X-Band Phased Array Antenna (XPAA)

Technology Need:

High rate, reliable RF communication subsystems

Description:

The X-band phased array antenna is composed of a flat grid of many radiating elements whose transmitted signals combine spatially to produce desired antenna directivity (gain)

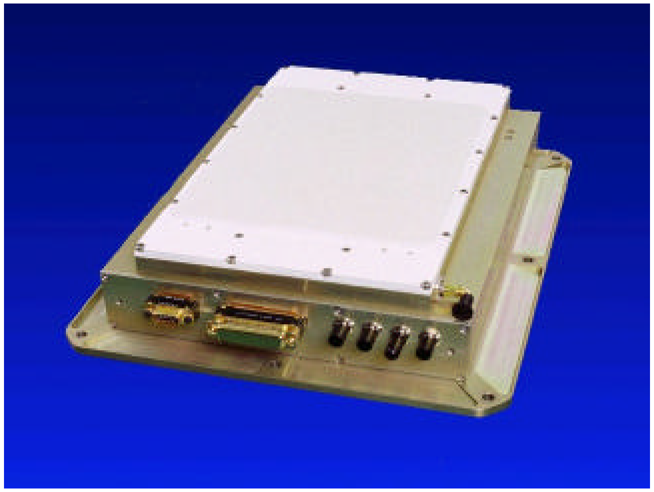
– *Avoids problems of deployable structures and moving parts*
– *Lightweight, compact, supports high downlink (100’s Mbps) rates.*
– *Allows simultaneous instrument collection and data downlink.*

Validation:

The XPAA will be validated through measurement of bit error rate performance and effective ground station EIRP during science data downlinks over the lifetime of the mission.

Commercial Partners:

Boeing Phantom Works



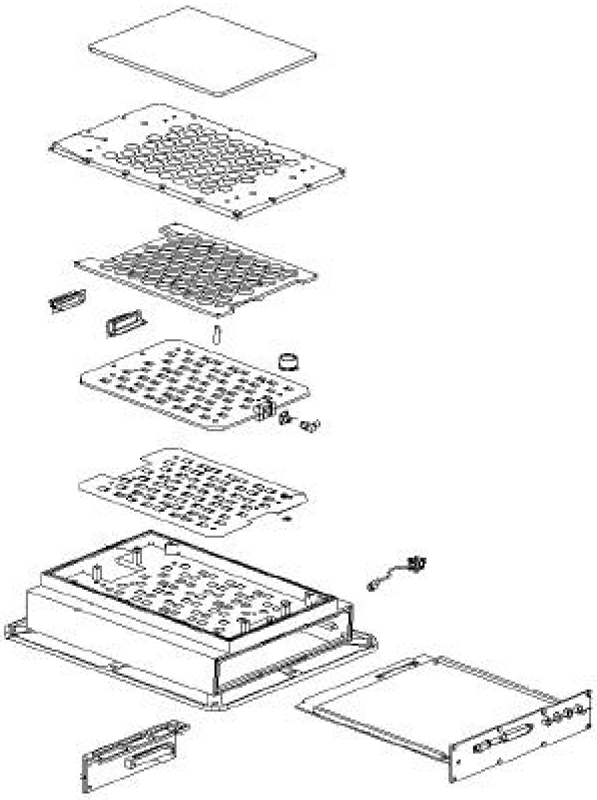
Benefits to Future Missions:

Future Earth Science missions will produce tera-bit daily data streams. The Phase Array antenna technology will enable:

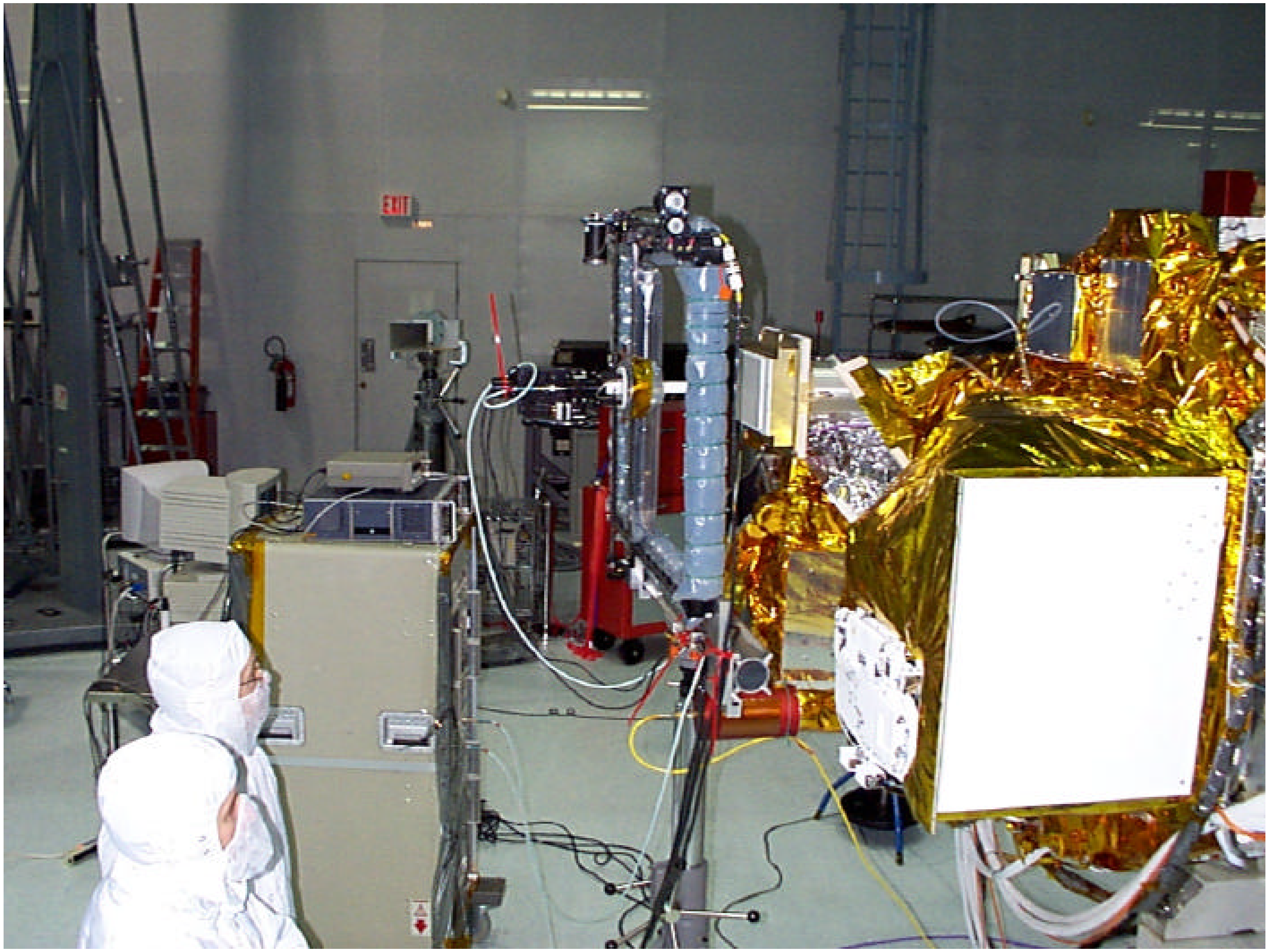
– *Lower cost, weight and higher performance science downlinks*
– *Lower cost and size ground stations*
– *More flexible operations*

XPAA Performance Summary

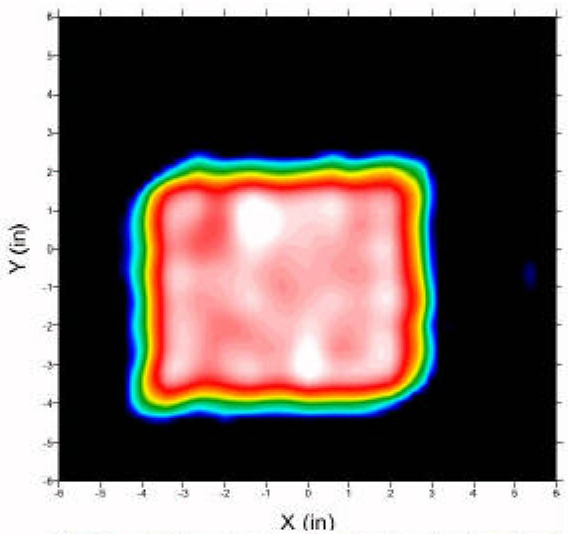
- *Frequency - 8225 MHz*
- *Bandwidth - 400 MHz*
- *Scan Coverage - 60 deg half-angle cone*
- *Radiating Elements - 64*
- *RF Input - 14 dBm*
- *EIRP - greater than 22 dBW at all commanded angles*
- *Polarization - LHCP*
- *Command Interface / Controller - 1773 / RSN*
- *Input DC Power - <58 watts over 0 to 40 C*
- *Mass - 5.5 kg*



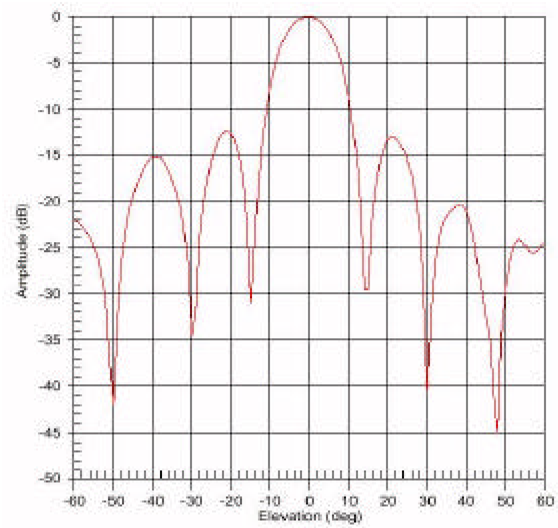
XPAA mounted on EO1, undergoing near-field scanning in the large clean room at GSFC.



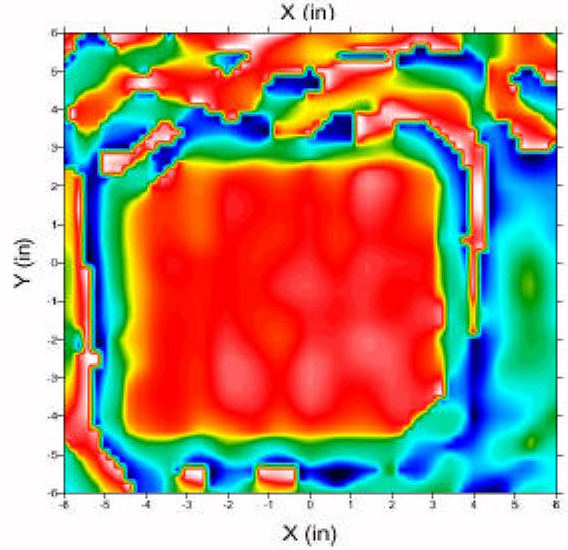
Near Field Measurement Data for the XPAA when Mounted on EO1



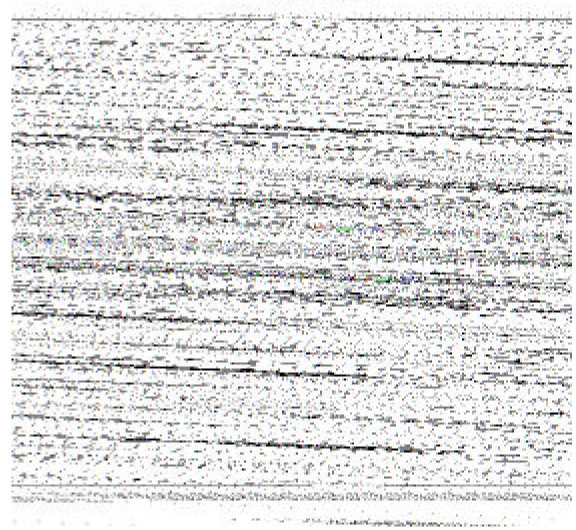
Aperture Amplitude



Far Field Cut



Aperture Phase



Far Field Contour

XPAA Initial Validation Summary

- ***Early post-launch experience with the XPAA revealed intermittent data errors while NASA ground antennas were autotracking the X-band signal. Currently, using S-band tracking and some additional passes, all science validation data is being successfully transmitted to ground using the XPAA.***
- ***A Tiger Team was established in December 2000 to find the cause:***
  - ***Initial validation measurements and on-board telemetry indicate that the XPAA is operating well and as-designed***
  - ***Alignment problems and other issues were found at the ground stations that are now being evaluated and rectified***
  - ***This is the first X-band satellite with a Left-hand Circularly Polarized signal to be tracked by these stations***
  - ***Several other commercial ground stations have had little or no difficulties in receiving the data.***
  - ***All Tiger Team results will be included in the Technology Transfer Documentation***

XPAA Technology Infusion Opportunities

- ***Design is owned by Boeing Phantom Works in Seattle, WA.***
- ***Boeing is interested in the commercial sale of their phased array antennas similar to the EO-1 antenna***
  - ***The phased array antenna is applicable to missions requiring:***
    - *Low mass antenna*
    - *High reliability with graceful degradation*
    - *Agile, accurate antenna pointing with no physical disturbance to the spacecraft*
- ***NASA support to facilitate infusion is negotiable***
- ***For further information contact:***

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Enhanced Formation Flying (EFF)

Technology Need:

Constellation Flying

Description:

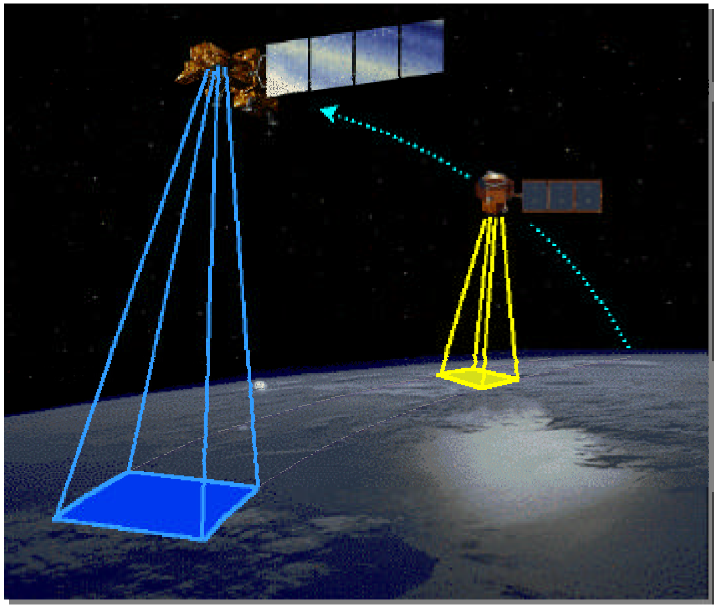
The enhanced formation flying (EFF) technology features flight software that is capable of autonomously planning, executing, and calibrating routine spacecraft maneuvers to maintain satellites in their respective constellations and formations.

Validation:

Validation of EFF will include demonstrating on-board autonomous capability to fly over Landsat 7 ground track within a +/- 3km while maintaining a one minute separation while an image is collected.

Partners:

JPL,GSFC, Hammers



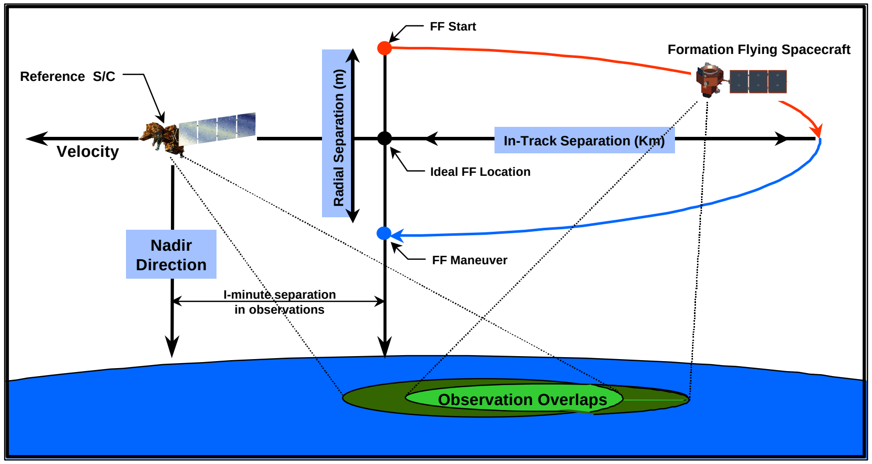
Benefits to Future Missions:

The EFF technology enables small, inexpensive spacecraft to fly in formation and gather concurrent science data in a “virtual platform.”

This “virtual platform” concept lowers total mission risk, increases science data collection and adds considerable flexibility to future Earth and space science missions.

Performance Required

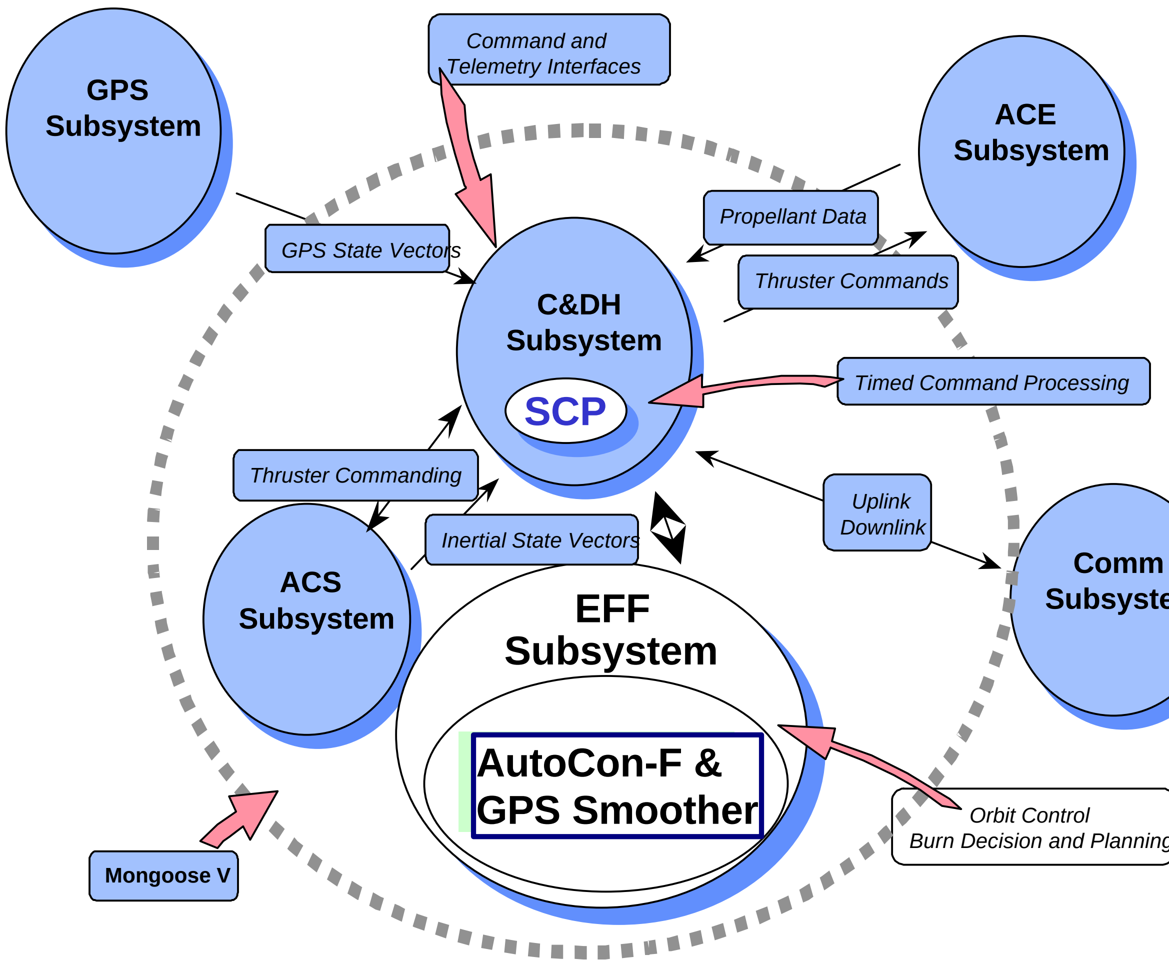
- ***Mission Orbit Requirements***
  - *Paired scene comparison requires EO-1 to fly in formation with Landsat-7.*
  - *Maintain EO-1 orbit with tolerances of:*
    - *One minute separation between spacecraft*
    - *Maintain separation so that EO-1 follows current Landsat-7 ground track to +/- 3 km*
- ***Derived Orbit Requirements***
  - *Approximately six seconds along-track separation tolerance (maps to +/- 3km with respect to earth rotation)*
  - *Plan maneuver in 12 hours*
- ***Derived Software Constraints***
  - *Code Size approximately »655Kbytes*
  - *CPU Utilization approximately <50% Average over 10 Hours during maneuver planning*
  - *Less than 12 hours per maneuver plan*



EO-1 Formation Maneuver Frequency Is Ballistic Dependent

Subsystem Level

- **Verify**
  - *EFF*
  - *AutoCon-F*
    - GSFC
    - JPL
    - GPS Data Smoother
  - *SCP*
  - *Algorithm Flight Code Uploads for JPL into RAM*



Enhanced Formation Flying

Technology Infusion Opportunities

- ***Enhanced Formation Flying technology is owned by NASA***
- ***It is applicable to missions that require:***
  - *Constellations*
  - *"Virtual" platforms that involve the coordinated use of instruments on different spacecraft*
  - *Autonomous operations*
- ***NASA support to facilitate infusion is negotiable***
- ***For further information contact:***

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Carbon-Carbon Radiator

Technology Need:

Increase instrument payload mass fraction.

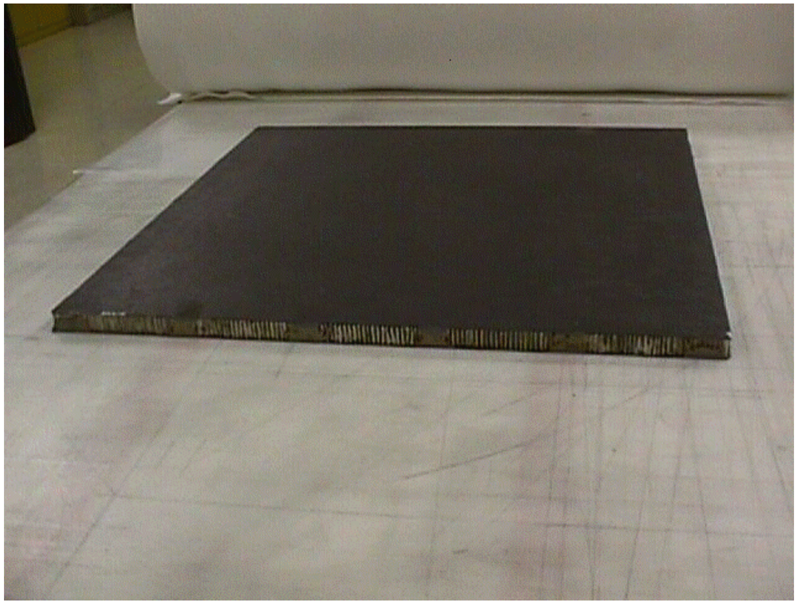
Description:

Carbon-Carbon is a special composite material that uses pure carbon for both the fiber and matrix. The NMP Earth Orbiter – 1 mission will be the first use of this material in a primary structure, serving as both an advanced thermal radiator and a load bearing structure Advantages of Carbon-Carbon include:

– *High thermal conductivity including through thickness*
– *Good strength and weight characteristics*

Validation:

EO-1 will validate the Carbon-Carbon Radiator by replacing one of six aluminum 22” x27” panels with one constructed using the C-C composite materials. Mechanical and thermal properties of the panels will be measured and trended during environmental testing and on-orbit.



Benefits to Future Missions:

This technology offers significant weight reductions over conventional aluminum structures allowing increased science payload mass fractions for Earth Science Missions. Higher thermal conductivity of C-C allows for more space efficient radiator designs.

Partners

CSRP (consortium)

Design Overview

- *Equipment panel (Bay #4) composed of carbon-carbon facesheets and an aluminum honeycomb core*
- *Supports the LEISA and PSE*
- *Measures 28.62 x 28.25 x 1.00 in*
- *Mass of 3.12 kg*
- *Flight unit and spare*
- *Design stable since CDR*

Performance Required

- ***Mass - Less than 2.5 kg***
- ***Stiffness - First mode frequency greater than 100 Hz when hard-mounted to the S/C***
- ***Strength - Inertial loading***
  - ***Simultaneous quasi-static limit and S/C interface loads***
    - *15 g acceleration in any direction*
    - *Shear load of 16,100 N/m*
    - *Edge normal load of 19,500 N/m*
    - *Panel normal load of 1,850 N/m*
  - ***Maximum fastener forces at the S/C attachment points***
    - *Maximum tension force of 25 N*
    - *Maximum shear force normal to panel edge of 135 N*
    - *Maximum shear force parallel to panel edge of 115 N*
- ***Strength - Thermal loading***
  - ***On-orbit temperature variations ranging from -20°C to +60°C***

Carbon-Carbon Radiator

Technology Infusion Opportunity

- ***Design is owned by Carbon-Carbon Spacecraft Radiator Partnership (CSRP)***
- ***This technology is applicable to missions requiring:***
  - ***Lightweight, efficient radiators with favorable structural properties***
  - ***Structural properties and thermal properties can be balanced in the manufacturing process***
- ***The CSRP is interested in providing these radiators to interested parties***
- ***NASA support to facilitate infusion is negotiable***
- ***For more information contact:***

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Pulse Plasma Thruster (PPT)

Technology Need:

Increased payload mass fraction and precision attitude control

Description:

The Pulse Plasma Thruster is a small, self contained electromagnetic propulsion system which uses solid Teflon propellant to deliver high specific impulses (900-1200sec), very low impulse bits (10-1000uN-s) at low power.

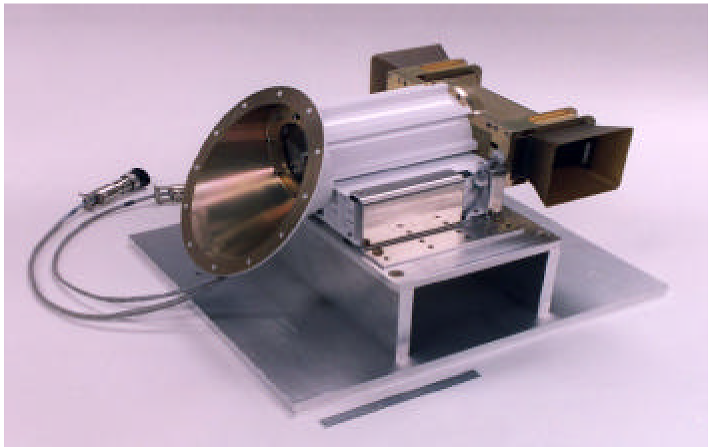
Advantages of this approach include:

- *Ideal candidate for a low mass precision attitude control device.*
- *Replacement of reaction control wheels and other momentum unloading devices. Increase in science payload mass fraction.*
- *Avoids safety and sloshing concerns for conventional liquid propellants*

Validation:

The PPT will be substituted (in place of a reaction wheel) during the later phase of the mission (month 11). Validation will include:

- *Demonstration of the PPT to provide precision pointing accuracy, response and stability.*
- *Confirmation of benign plume and EMI effects*



Benefits to Future Missions:

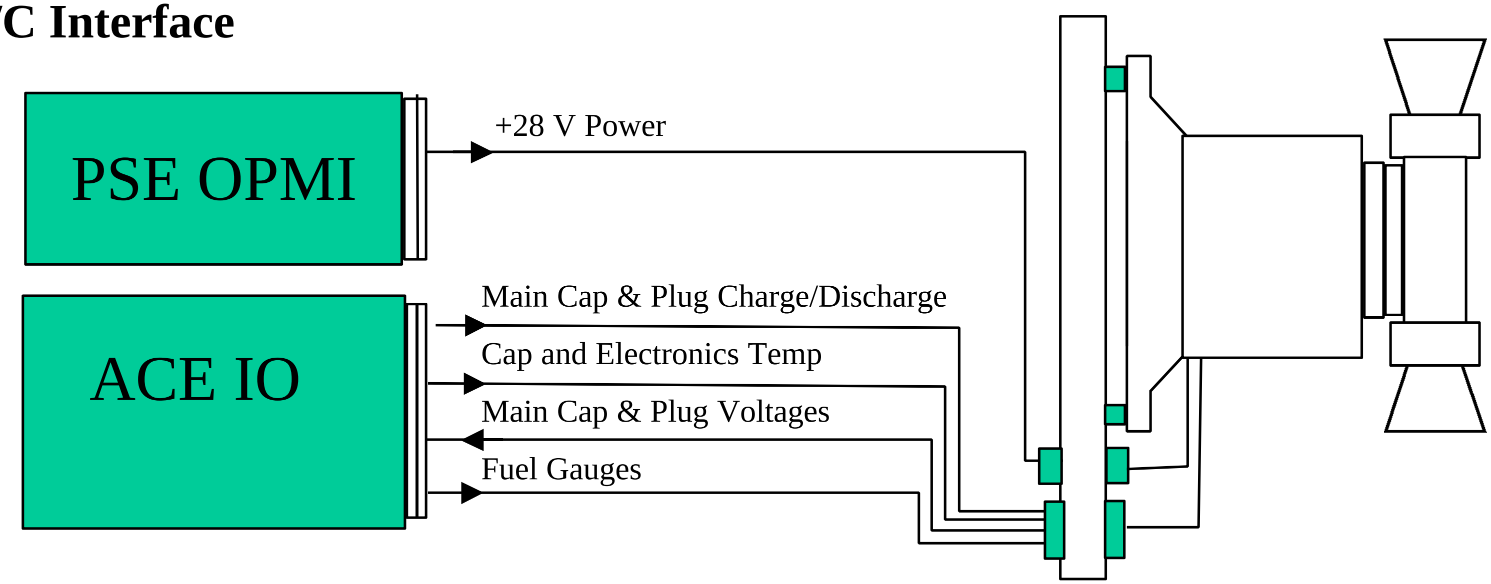
The PPT offers new lower mass and cost options for fine precision attitude control for new space or earth science missions

Partners

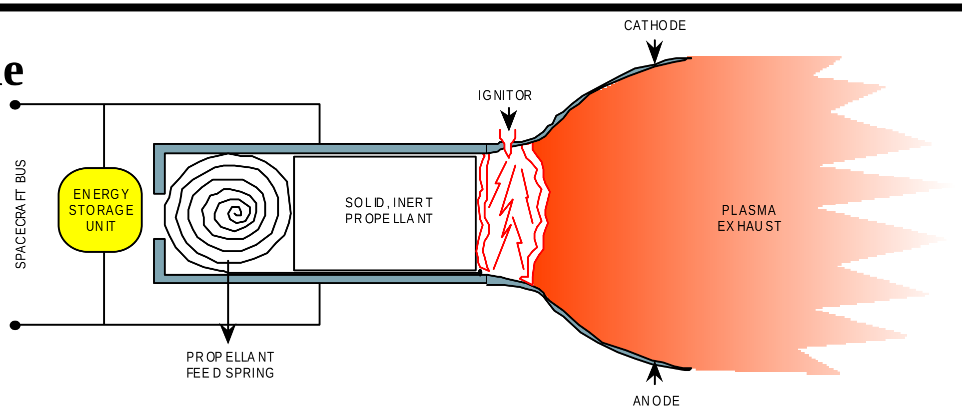
GRC, Primex, GSFC

PPT Design

S/C Interface



Technology Principle



ABLATION ⟶ IONIZATION ⟶ ACCELERATION

Pulse Plasma Thruster

Technology Infusion Opportunity

- ***Design is owned by Primex***
- ***Validation scheduled for October / November 2001***
- ***EO-1 unit developed at the Glenn Research Center***
- ***Applicable to missions requiring:***
  - ***Low mass, precision attitude control***
  - ***Highly reliable***
- ***Primex will provide similar units to interested parties***
- ***NASA support to facilitate infusion is negotiable***
- ***For more information contact:***

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Lightweight Flexible Solar Array (LFSA)

Technology Need:

Increase payload mass fraction.

Description:

The LFSA is a lightweight photovoltaic(PV) solar array which uses thin film CuInSe2 solar cells and shaped memory hinges for deployment. Chief advantages of this technology are:

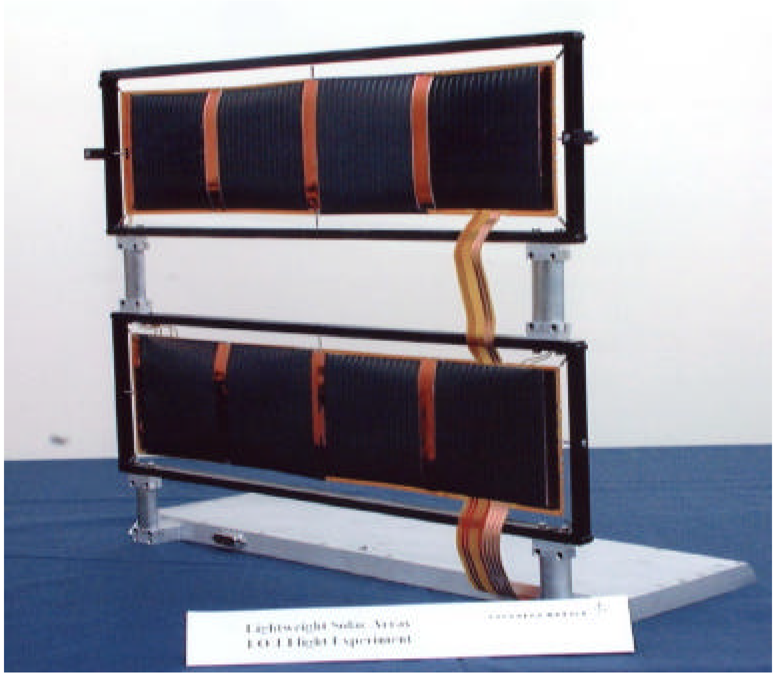
- *Greater than 100Watt/kg specific energies compared to conventional Si/GaAs array which average 20-40 Watts/kg.*
- *Simple shockless deployment mechanism eliminates the need for more complex mechanical solar array deployment systems. Avoids harsh shock to delicate instruments.*

Validation:

The LFSA deployment mechanism and power output will measured on-orbit to determine its ability to withstand long term exposure to radiation, thermal environment and degradation due to exposure to Atomic Oxygen.

Partners

Phillips Lab, Lockheed Martin Corp



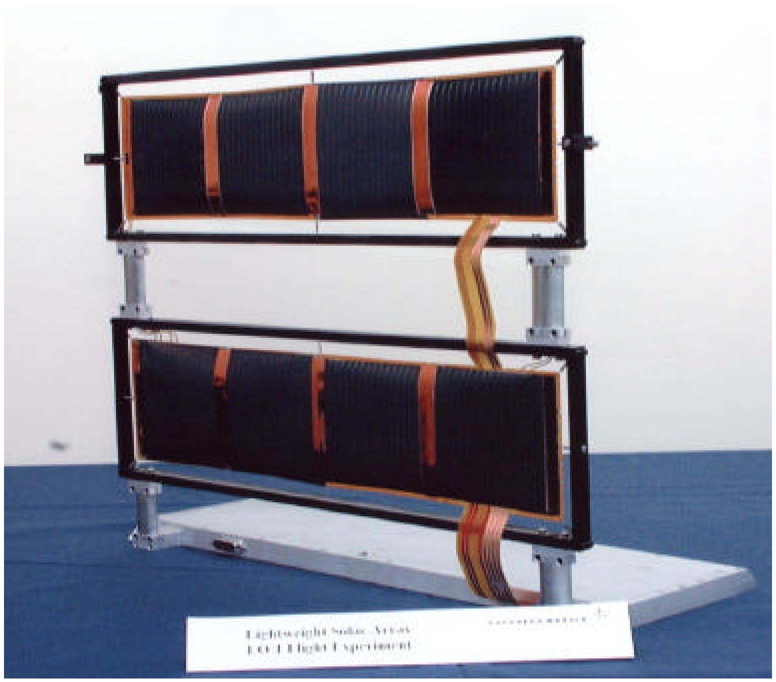
Benefits to Future Missions:

This technology provides much higher power to weight ratios (specific energy) which will enable future missions to increase science payload mass fraction.

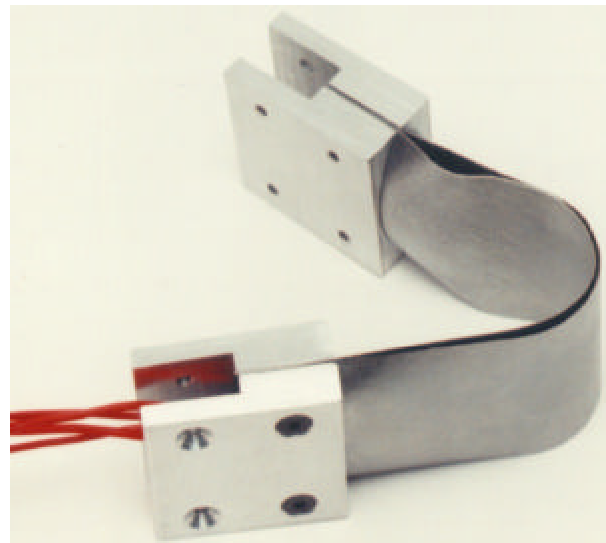
Description

- ***Copper Indium Diselenide ($CuInSe_2$ or CIS) Thin-Film Solar Cells***
- ***Deposited on a Flexible Kapton Blanket suspended in a Composite Frame***
- ***Frame Deployed Using Shape Memory NiTi Alloys and a Launch Restraint Device***
- ***Advantage: Increase solar array w/kg (from typical 40 w/kg to >100 w/kg), increase science payload mass fraction***
- ***Partners: AFRL (Kirtland AFB, NM), NASA/LaRC, Lockheed Martin (Denver, CO)***

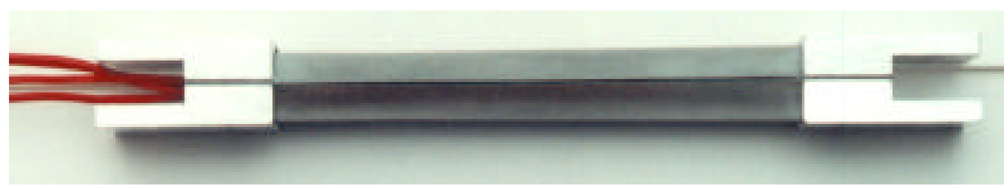
***Description** (continued)*



LFSA FLIGHT UNIT



SMA - STOWED



SMA - DEPLOYED

Lightweight Flexible Solar Array

Technology Infusion Opportunities

- ***Design is owned by Lockheed Martin***
- ***Developed by Air Force Research Lab***
- ***Applicable to missions requiring low mass solar array***
- ***Shaped memory hinges provide simple, shockless deployment***
- ***Lockheed Martin will provide similar systems to interested parties***
- ***NASA support to facilitate infusion is negotiable***
- ***For more information contact:***

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